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Monitoring and characterizing offshore wind variability with weather radars for wind energy applications

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Google search: “wind energy + weather radar”

The screenshot shows a Google search results page for the query "wind energy + weather radar". The search bar at the top contains the text "wind energy + weather radar" and a magnifying glass icon. Below the search bar, the results are categorized under "Web". The first result is a PDF document titled "Doppler Weather Radars and Wind Turbines - InTech" from intechopen.com. The second result is "Wind Turbine Interference with Weather Radar" from ec.gc.ca. The third result is "Weather radar - Wikipedia, the free encyclopedia". The fourth result is "IEEE Xplore - Wind Turbine Clutter mitigation for weather radar by ...". The fifth result is "Concerns Grand Bend wind turbines could affect weather radar" from london.ctvnews.ca. The sixth result is "Wind Farm Interference Showing Up on Doppler Radar - National ...".

Google

wind energy + weather radar

Web Images Maps Shopping Plus Outils de recherche

Environ 26 300 000 résultats (0,29 secondes)

[PDF](#) [Doppler Weather Radars and Wind Turbines - InTech](#)
www.intechopen.com/download/pdf/35119 Traduire cette page
 0. Doppler **Weather Radars** and **Wind Turbines**. Lars Norin and Günther Haase.
 Swedish Meteorological and Hydrological Institute, Sweden. 1. Introduction.
 Vous avez consulté cette page 2 fois. Dernière visite : 12/06/13

[Wind Turbine Interference with Weather Radar](#)
www.ec.gc.ca/meteo-weather/default.asp?lang=En... Traduire cette page
 30 avr. 2013 – Information for **wind farm** developers and the general public on the
 interference between **wind turbines** and **weather radar** in Canada.

[Weather radar - Wikipedia, the free encyclopedia](#)
https://en.wikipedia.org/wiki/Weather_radar
 Aller à [Wind farms](#) – [edit]. Reflectivity (left) and radial velocities (right) southeast of a
 NEXRAD **weather radar**. Echoes in circles are from a **wind farm**.

[IEEE Xplore - Wind Turbine Clutter mitigation for weather radar by ...](#)
ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber... Traduire cette page
Wind Turbine Clutter (WTC) is the **radar** clutter caused by strong backscatter from
 large **wind turbines** within the **radar** vicinity. Due to the rotation of the rotor ...

[Concerns Grand Bend wind turbines could affect weather radar](#)
london.ctvnews.ca/concerns-grand-bend-wind-turbine... Traduire cette page
 21 févr. 2013 – Tests on the proposed Grand Bend **Wind Farm** indicate it could cause
 problems for Environment Canada's **weather radar** station in Exeter, Ont.

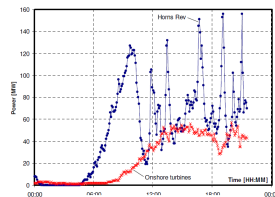
[Wind Farm Interference Showing Up on Doppler Radar - National ...](#)
www.erh.noaa.gov/buf/windfarm.htm Traduire cette page
 6 juin 2005 – The National **Weather Service** in Buffalo, NY, serves the Western and

Building wind power forecasts – The Danish offshore experience

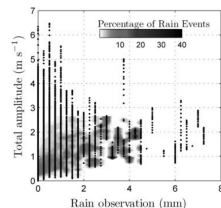


(summarized) DIALOGUE

- **wind farm operator (wfo):** "I observe significant differences in wind power variability onshore and offshore. How come such differences?"
- **meteorologist:** "This is because of large offshore wind farm layout concentrating many wind turbines within a small geographical area. There is no smoothing effect!"
- **meteorologist:** "But not only. Offshore wind dynamics are also very different owing to enhanced convection over waters."
- **wfo:** "It is true. I often observe very intense rain showers during episodes of large wind (power) fluctuations."
- **statistician:** "I don't understand the causes but wind time series show very sudden changes in variability."
- **meteorologist:** "I performed a mesoscale analysis of the weather and I also noticed that enhanced wind fluctuations are often correlated with the occurrence of heavy precipitation in the vicinity of the wind farm."
- **wfo:** "Can you provide me with new/specific wind power forecasts so that I can better handle these situations?"
- **meteorologist:** "I could use a weather radar to monitor weather conditions in the vicinity of the wind farm and assimilate precipitation data into a local NWP models."
- **statistician:** "I could ultimately develop regime-switching models based on the NWP forecasts and the information provided by the weather radar."



(Source: Kristoffersen (2005))



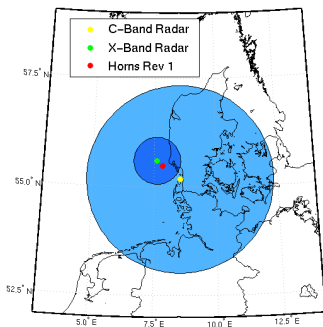
(Source: Vincent et al. (2011))

Radar@Sea (2009-2012) – Partners



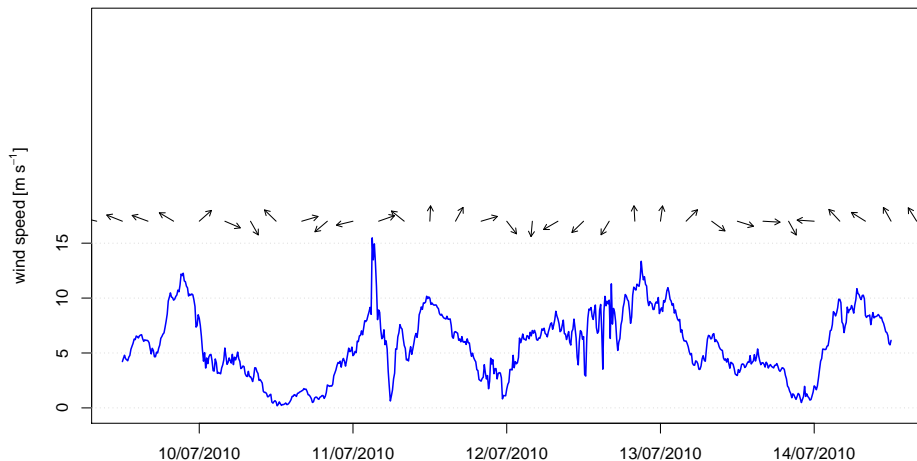
Experimental design

| | ● LAWR (X-Band) | ● Doppler (C-Band) |
|---------------------|---------------------------------|--------------------------------|
| Location | Offshore (~15 km from HR1 ●) | Onshore (~70 km from HR1 ●) |
| Range | small | long |
| Spatial resolution | fine | coarse |
| Temporal resolution | high | low |



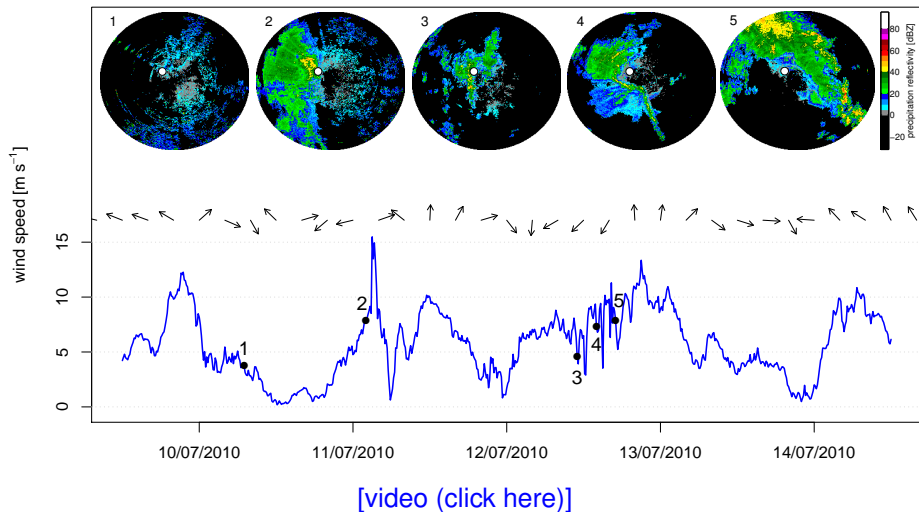
X-Band radar at Horns Rev

Data example: Summer season

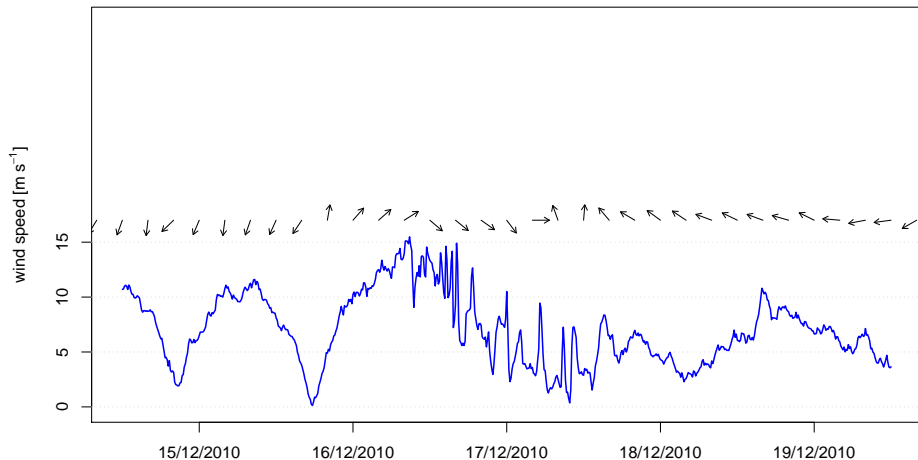


[\[video \(click here\)\]](#)

Data example: Summer season

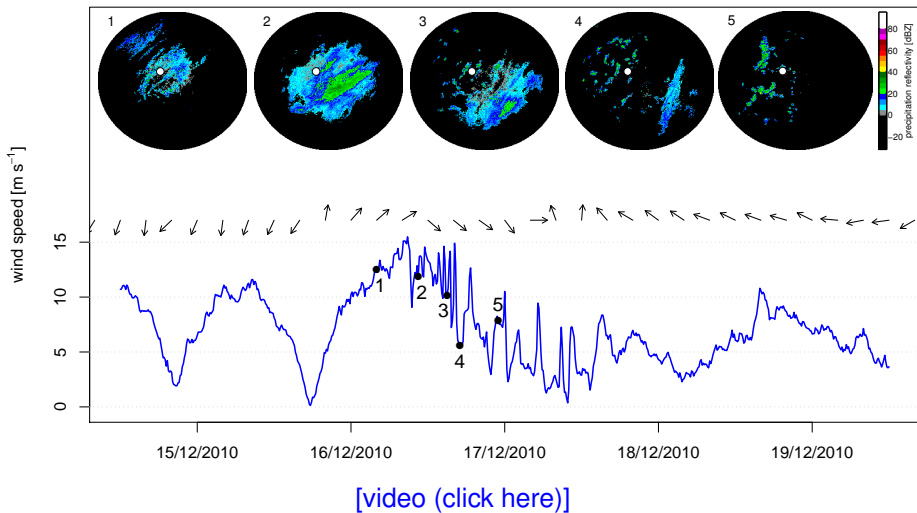


Data example: Winter season

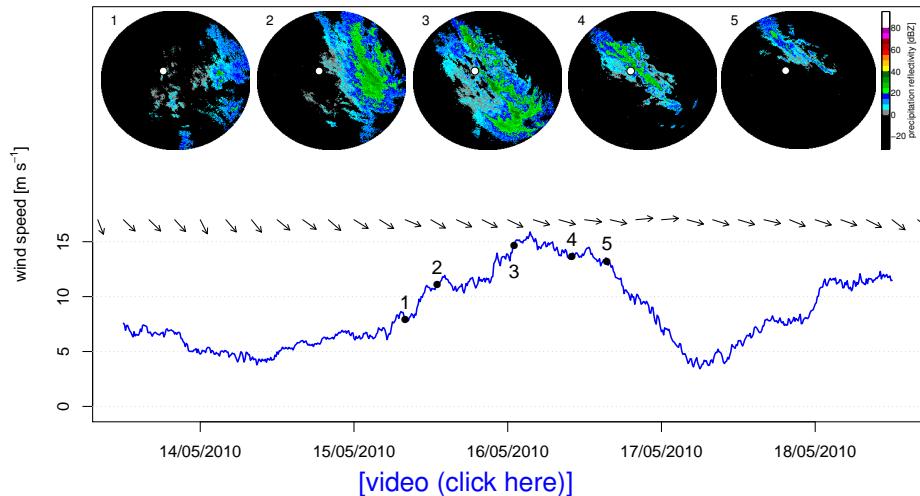


[\[video \(click here\)\]](#)

Data example: Winter season



Data example: Spring season



Status & Goals

- The assimilation of weather radar data (Doppler C-Band) into a local NWP models has just started,
- So far, most work consisted of data mining (i.e, explorative analysis of the data with statistical tools):
 - objective: improve the understanding of offshore wind speed variability with the information extracted from weather radar observations,
 - initial focus on the observations produced by the Doppler C-Band,
 - develop automatic procedure (with very little knowledge expert)
- Present results in a easy-to-interpret manner:
 - graphic based,
 - low dimensional outputs.

Wind speed variability index

- Time series segmentation**

Markov-Switching model + Global Decoding algorithm = categorical index

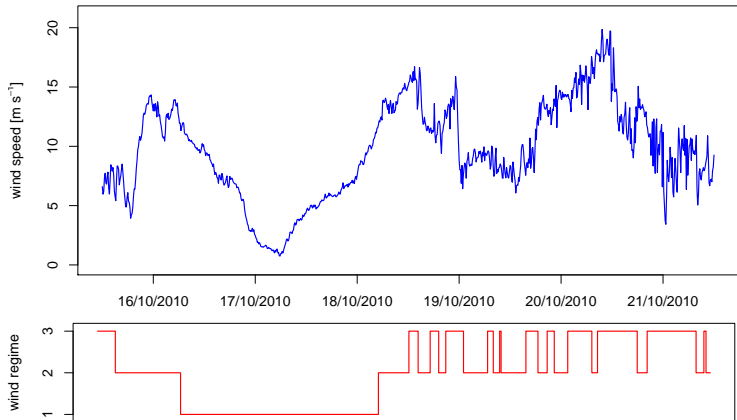


Figure: Segmenting into 3 regimes

Wind speed variability index

- Time series segmentation**

Markov-Switching model + Global Decoding algorithm = categorical index

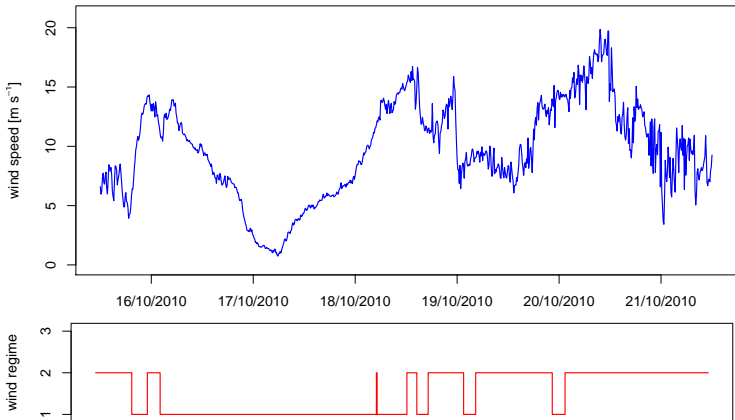


Figure: segmenting into 2 regimes

Wind speed variability index

- Time series segmentation**

Markov-Switching model + Global Decoding algorithm = categorical index

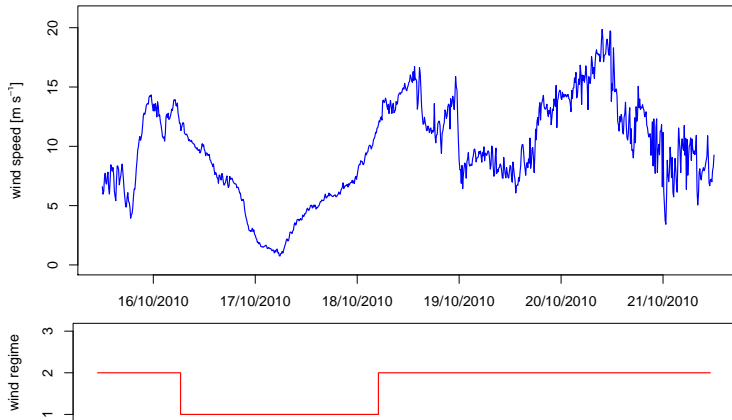
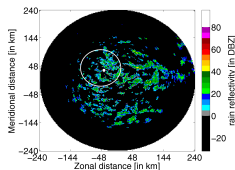
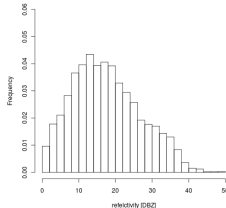


Figure: Segmenting into 3 regimes initially but merging regimes #2 and #3

Global attributes from weather radar images

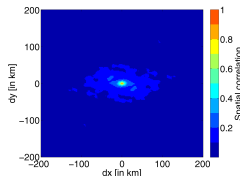


Reflectivity distr.



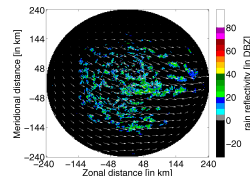
median, quantile 99%
(robust estimator of
maximum value), ...

Spatial Continuity



Area & Ellipticity

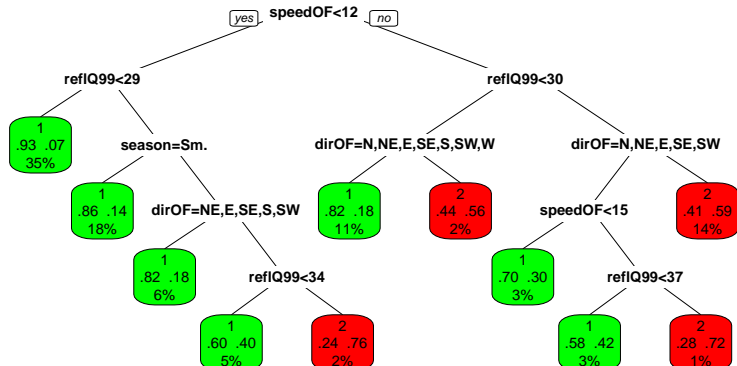
Motion



Speed & Direction

Wind variability classification

- Method: Classification and Regression Trees (CART)



- learning #1: importance of particular attributes (speed, direction and max reflectivity),
- learning #2: we cannot go global, need for local attributes.

Conclusion

- There is a mutual interest for weather radar and wind energy communities to collaborate,
- Methodological proposal for mining offshore wind farm and weather radar data (with focus on visual representation of the results),
- Confirmation of previous results [*Vincent et al.* (2011)],
- Statistical and data mining tools can help revealing interesting insights on meteorological data for energy applications,
- Future work:
 - consider 3D weather radar observations + radial winds
 - time series analysis over multi-scale,
 - object identification on weather radar images (e.g, small convective cells and storms)
 - consider other meteorological inputs (e.g. met. forecasts from NWP models, satellite images),
 - integrate weather radar data into a prediction system.

Thank you for your attention!

References and further reading:

Kristoffersen JR. **The Horns Rev wind farm and the operational experience with the wind farm main controller**. In Proceedings of the *Offshore Wind International Conference and Exhibition*, Copenhagen, Denmark, 2005.

Lakshmanan V, Smith T, Stumpf G, Hondl K. **The Warning Decision Support System-Integrated Information**. *Weather and Forecasting*, vol. 22, pp 596–612, 2007.

Vincent C, Pinson P, Giebel G. **Wind fluctuations over the North Sea**. *International Journal of Climatology*, vol. 31, pp. 1584–1595, 2011.

Pinson P, Madsen H. **Adaptive modeling and forecasting of wind power fluctuations with Markov-switching autoregressive models**. *Journal of Forecasting*, vol. 31, pp. 281–313, 2012.

Trombe P-J, Pinson P, Madsen H. **Automatic classification of offshore wind regimes with weather radar observations**. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, Available Online.

Trombe P-J, Pinson P, Vincent CL, Bøvith T, Cutululis N, Draxl C, Giebel G, Hahmann A, Jensen NE, Jensen BP, Le NF, Madsen H, Pedersen LB, Sommer A. **Weather radars – The new eyes for offshore wind farms?** *Wind Energy*, In press.